Original article

# Rural and urban distribution of trauma incidents in Scotland

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**Background:** **Trauma systems reduce mortality and improve functional outcomes from injury. Regional trauma networks have been established in several European regions to address longstanding deficiencies in trauma care. A perception of the geography and population distribution as challenging has delayed the introduction of a trauma system in Scotland. The characteristics of trauma incidents attended by the Scottish Ambulance Service were analysed, to gain a better understanding of the geospatial characteristics of trauma in Scotland.**

**Methods:** **Data on trauma incidents collected by the Scottish Ambulance Service between November 2008 and October 2010 were obtained. Incident location was analysed by health board region, rurality and social deprivation. The results are presented as number of patients, average annual incidence rates and relative risks.**

**Results:** **Of the 141 668 incidents identified, 72·1 per cent occurred in urban regions. The risk of being involved in an incident was similar across the most populous regions, and decreased slightly with increasing rurality. Social deprivation was associated with greater numbers and risk. A total of 53·1 per cent of patients were taken to a large general hospital, and 38·6 per cent to a teaching hospital; the distribution was similar for the subset of incidents involving patients with physiological derangements.**

**Conclusion:** **The majority of trauma incidents in Scotland occur in urban and deprived areas. A regionalized system of trauma care appears plausible, although the precise configuration of such a system requires further study.**

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## Introduction

The configuration of a trauma system must reflect the demographic and geospatial characteristics of its target population. High-level trauma centres require a case volume sufficient to permit institutional experience to develop[1–3], but must be accessible within a reasonable time. The provision of trauma care in regions with large rural areas and eccentrically distributed populations poses particular challenges[4–9].

Although trauma systems have been in existence in North America for several decades, Britain has, historically, not had a comparable framework for the delivery of trauma care. However, over the past decade increasing recognition of the inadequacy of existing services[10–14] has led to the establishment of a national network of regional trauma systems in England. In contrast, Scotland has no current plans for the parallel development of a trauma network, although the Royal College of Surgeons of Edinburgh has recently published a report calling for such a system[15]. Scotland's reticence to embrace regionalized trauma care is, at least in part, due to a perception that admission to the nearest hospital, regardless of capability, is preferable to transport to a more distant facility, even if such a facility is better resourced[16,17].

Scotland's population of approximately 5 million is concentrated in four conurbations – Glasgow, Edinburgh, Dundee and Aberdeen – which are located in the south-west, south-east, east and north-east of the country. The population of the greater Glasgow area, which accounts

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for a fifth of the Scottish population, far exceeds that of the other three cities. Large parts of Scotland, particularly in the north-west of the country, are very rural and sparsely populated. This situation is not unique; there are many other regions, in the UK, Europe and North America, that face similar challenges[7–9,18]. Furthermore, the relationship between population distribution and trauma incident distribution is complex. Penetrating trauma, for example, tends to be associated with urban areas and social deprivation. Decisions regarding trauma service delivery should be based on the geographical distribution of incident locations, rather than the population as a whole. The aim of this study was to conduct an analysis of the demographic characteristics and geospatial distribution of incidents attended by the Scottish Ambulance Service, to inform the debate regarding the delivery of major trauma services in Scotland.

## Methods

This was a retrospective analysis of data routinely collected by the Scottish Ambulance Service's electronic patient record system. The system, which was introduced in 2006, contains information on incident location, patient demographics, vital signs, dispatch determinants and destination hospital. These data are recorded prospectively. The dispatch code, an important part of the record, is generated initially by a caller interrogation system (Medical Priority Dispatch System™; Priority Dispatch, Salt Lake City, Utah, USA). Using the same system, a separate, final diagnostic code is subsequently recorded by ambulance crews to document a patient's diagnosis, based on their assessment. The first two-digit component of the code refers to the protocol (or 'card') and indicates a broad category of emergency (for example protocol 04 indicates assaults).

### Case definition

The final Medical Priority Dispatch System™ code was used to extract data pertaining to incidents involving traumatic injury. The study included all incidents among adult patients (aged 14 years and older) attended between 1 November 2008 and 31 October 2010 that were recorded as assaults (protocol 04), falls (protocol 17), penetrating injuries (protocol 27), traffic and transportation injuries (protocol 29) or other traumatic injuries (protocol 30). Children under the age of 14 years were excluded because the organization of paediatric trauma care differs from that of adults. Episodes with missing location postcodes were also excluded.

### Study variables

Extracted data included patient demographics, physiological status (systolic blood pressure, respiratory rate and Glasgow Coma Scale (GCS) score), mechanism of injury and postcode of the incident location.

Physiological disturbance was categorized as impaired mental status (GCS score below 14), hypotension (systolic blood pressure less than 90 mmHg) and abnormal respiratory rate (below 10 or above 29 per min), in accordance with the Center for Disease Control's Field Triage Decision Scheme[19]. This scheme is used in North America to triage patients to trauma centre care, and is based on physiological, anatomical and mechanism of injury criteria. However, the Scottish Ambulance Service presently records only physiological data, precluding the retrospective application of the remaining triage steps. Missing values were treated as missing, and were not included in subsequent numerical analyses. Mechanism of injury was defined by final Medical Priority Dispatch System™ code. Incidents recorded as protocol 27 were coded as 'penetrating' and all other incidents as 'blunt'.

Incident locations were coded by health board region, using postcode look-up tables available from the Scottish Government. The rurality of the incident location was graded using the eight-point Scottish Urban Rural Classification (SURC)[20]. Social deprivation was graded using the Scottish Index of Multiple Deprivation (SIMD)[21]. The level of the destination healthcare facility was coded as teaching hospital, large general hospital, general hospital, children's hospital, maternity hospital, community hospital or other specialist hospital, using the Scottish Government classification[22]. In 2010, teaching hospitals, large general hospitals and general hospitals in Scotland had a median of 878 (range 564–1014), 415 (183–695) and 60 (19–198) staffed beds respectively[22].

Outcomes are presented as the number of incidents, incident rate per 100 000 population per year and relative risk (relative to the remainder of the population), by health board region, SURC and decile of SIMD.

### Statistical analysis

Data were initially processed using Microsoft® Excel (Microsoft, Redmond, Washington, USA), using multiple pivot tables, to derive descriptive measures and perform postcode look-ups. Incidence rates were calculated using Scottish Census data from April 2009, the approximate midpoint of the 2-year study period, as the denominator. $\chi^2$ tests were used to compare categorical data, $t$ tests for normally distributed continuous variables and Mann–Whitney $U$ rank-sum tests for non-normally

distributed variables. SPSS® version 19.0 (IBM, Armonk, New York, USA) was used for statistical analysis.

## Results

After excluding patients with missing or erroneous postcodes (1109), a total of 141 668 incidents meeting the inclusion criteria were identified and analysed. Among excluded patients, there was a greater proportion of males (56·5 *versus* 50·6 per cent; $P = 0·009$), but no difference in median (interquartile range) age (55 (42–68) *versus* 54 (40–68) years; $P = 0·409$) or the proportion of patients with physiological disturbance (4·3 *versus* 4·4 per cent; $P = 0·903$). Owing to minor changes in postcodes, and resulting inaccuracies in the look-up tables, 214 incident locations (0·2 per cent) could not be matched to a health board region, 568 (0·4 per cent) could not be matched to a multiple deprivation index data zone and 2286 (1·6 per cent) could not be matched to a SURC category. A small number of incidents occurred in England (0·001 per cent), but resulted in transfer to a Scottish hospital, and therefore could not be allocated to a Scottish health board region.

### Demographic analysis

The characteristics of the study group are shown in *Table 1*. More incidents involved males (71 659, 50·6 per cent) than females (65 074, 45·9 per cent). Sex was not recorded in 4935 of incidents (3·5 per cent), and age in 11 468 (8·1 per cent). The median age of casualties who had their age recorded was 58 (interquartile range 31–79) years. The vast majority of incidents were caused by a blunt mechanism of injury (140 231, 99·0 per cent). Only 1437 incidents (1·0 per cent) were classified as resulting in penetrating injuries. The GCS score was not available for 15 014 incidents (10·6 per cent), systolic blood pressure for 24 315 (17·2 per cent) and respiratory rate was not available for 6112 (4·3 per cent).

Physiological derangements that would – in other settings – have resulted in triage to a level 1 or major trauma centre were found in 6236 patients. Patients who sustained penetrating injuries were younger than those with blunt trauma (median 26 *versus* 59 years respectively; $P < 0·001$). They were also more likely to be male (85·1 *versus* 50·2 per cent respectively; $P < 0·001$) and to have physiological disturbances (6·7 *versus* 4·4 per cent; $P = 0·002$).

### Incident location by health board region

The geographical distribution of the incidents, by health board region, is shown in *Table 2*, *Fig. 1* and *Fig. S1* (supporting information). The greatest number of incidents occurred in the predominantly urban Greater Glasgow and Clyde (37 733), Lothian (22 303) and Lanarkshire (16 133) health board regions. The more rural Borders and islands had the lowest number of incidents. The relative risk of being involved in an incident involving injury was also highest in the Greater Glasgow and Clyde health board region (1·21, 95 per cent confidence interval 1·20 to 1·23), and lowest in Shetland (0·60, 0·54 to 0·67), but was similar across the most populous health board regions (*Fig. 2*). *Table 2* also shows the incidence rates for each region, which paralleled the relative risks, ranging from 1573 per 100 000 population per year in Greater Glasgow and Clyde to 819 per 100 000 per year in Shetland,

**Table 1** Characteristics of study population, overall and by mechanism of injury

| | All incidents ($n = 141 668$) | Mechanism of injury | | |
|---|---|---|---|---|
| | | Blunt trauma ($n = 140 231$) | Penetrating trauma ($n = 1437$) | *P*§ |
| Age (years)*† | 58 (31–79) | 59 (32–80) | 26 (21–36) | < 0·001¶ |
| Sex‡ | | | | |
| M | 71 659 (50·6) | 70 436 (50·2) | 1223 (85·1) | < 0·001 |
| F | 65 074 (45·9) | 64 939 (46·3) | 135 (9·4) | |
| Physiological disturbance | | | | |
| GCS < 14 | 3887 (2·7) | 3844 (2·7) | 43 (3·0) | 0·692 |
| SBP < 90 mmHg | 618 (0·4) | 591 (0·4) | 27 (1·9) | < 0·001 |
| Respiratory rate < 10 or > 29 per min | 1953 (1·4) | 1916 (1·4) | 37 (2·6) | < 0·001 |
| Any of above | 6236 (4·4) | 6140 (4·4) | 96 (6·7) | 0·002 |

Values in parentheses are percentages unless indicated otherwise; *values are median (interquartile range). †Of those with recorded age. ‡Percentages do not add up to 100 as the sex of the patient was not recorded for some incidents. GCS, Glasgow Coma Scale; SBP, systolic blood pressure. §$\chi^2$ test, except ¶Student's *t* test.

**Table 2** Number, rate and relative risk of incidents, by location (health board region)

| | Population in health board region* | All incidents (blunt and penetrating) | | Blunt trauma | | Penetrating trauma | |
|---|---|---|---|---|---|---|---|
| | | *n* | Incidence rate | *n* | Incidence rate | *n* | Incidence rate |
| Greater Glasgow and Clyde | 1 199 026 | 37 733 | 1573 | 37 061 | 1545 | 672 | 28 |
| Lothian | 826 231 | 22 303 | 1350 | 22 094 | 1337 | 209 | 13 |
| Lanarkshire | 562 215 | 16 133 | 1435 | 15 958 | 1419 | 175 | 16 |
| Grampian | 544 980 | 12 680 | 1163 | 12 616 | 1157 | 64 | 6 |
| Tayside | 399 550 | 10 592 | 1325 | 10 536 | 1318 | 56 | 7 |
| Ayrshire and Arran | 367 160 | 9652 | 1314 | 9566 | 1303 | 86 | 12 |
| Highland | 310 530 | 8378 | 1349 | 8336 | 1342 | 42 | 7 |
| Forth Valley | 291 383 | 7764 | 1332 | 7723 | 1325 | 41 | 7 |
| Fife | 363 385 | 7747 | 1066 | 7694 | 1059 | 53 | 7 |
| Dumfries and Galloway | 148 510 | 3912 | 1317 | 3893 | 1311 | 19 | 6 |
| Borders | 112 680 | 3053 | 1355 | 3038 | 1348 | 15 | 7 |
| Western Isles | 26 180 | 602 | 1150 | 602 | 1150 | 0 | 0 |
| Shetland | 22 210 | 364 | 819 | 362 | 815 | 2 | 5 |
| Orkney | 19 960 | 344 | 862 | 343 | 859 | 1 | 3 |
| England† | –‡ | 197 | – | 195 | – | 2 | – |
| Unmatched postcodes | –‡ | 214 | – | 214 | – | 0 | – |
| Total | 5 194 000 | 141 668 | 1364 | 140 231 | 1350 | 1437 | 14 |

Incidence rates are calculated per 100 000 population per year. *At April 2009. †Incidents that occurred at a location in England, but were dealt with by the Scottish Ambulance Service. ‡Size of reference population not known.

although the most populous regions, again, had broadly similar rates.

The number of incidents involving penetrating trauma was larger in Greater Glasgow and Clyde (672) – more than three times that of the next two regions, Lothian (209) and Lanarkshire (175) (*Table 2*). Furthermore, in contrast to blunt trauma, for which the relative risk of being involved in an incident was broadly similar across much of Scotland, the relative risk of being involved in a penetrating trauma incident was higher in the Greater Glasgow and Clyde area (2·93, 2·65 to 3·26) than in the next highest region (Lanarkshire: relative risk 1·14, 0·98 to 1·34) (*Fig. 2*). The incidence rate in the Greater Glasgow and Clyde region (28 per 100 000 population per year) was approximately twice that of Lanarkshire (16 per 100 000 per year), Lothian (13 per 100 000 population per year) and Ayrshire and Arran (12 per 100 000 population per year), and approximately four times that of the Borders, Fife, Highland, Forth Valley and Tayside (all 7 per 100 000 per year) (*Table 2*).

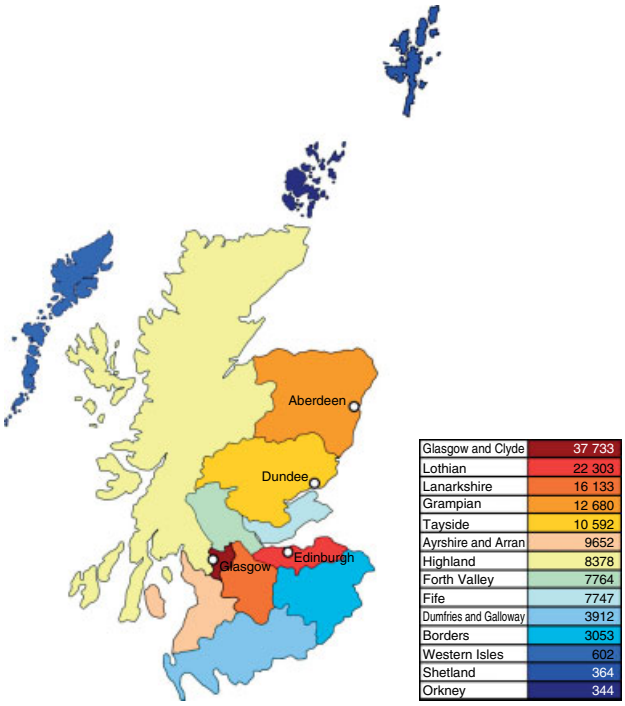


**Fig. 1** Geographical representation of number of trauma incidents, by health board region

## Association with rurality

The population of Scotland is distributed unevenly across the eight categories of the SURC. Specifically, 69·6 per cent of the population reside in urban areas (category 1 and 2), and only 6·5 per cent live in remote or very remote rural areas (category 7 and 8), whereas 11·6 per cent reside in accessible rural areas (category 6). The number of incidents broadly reflected this distribution (*Table S1*, supporting information), but the relative risk showed less variation (*Fig. 3*). Although slightly higher in

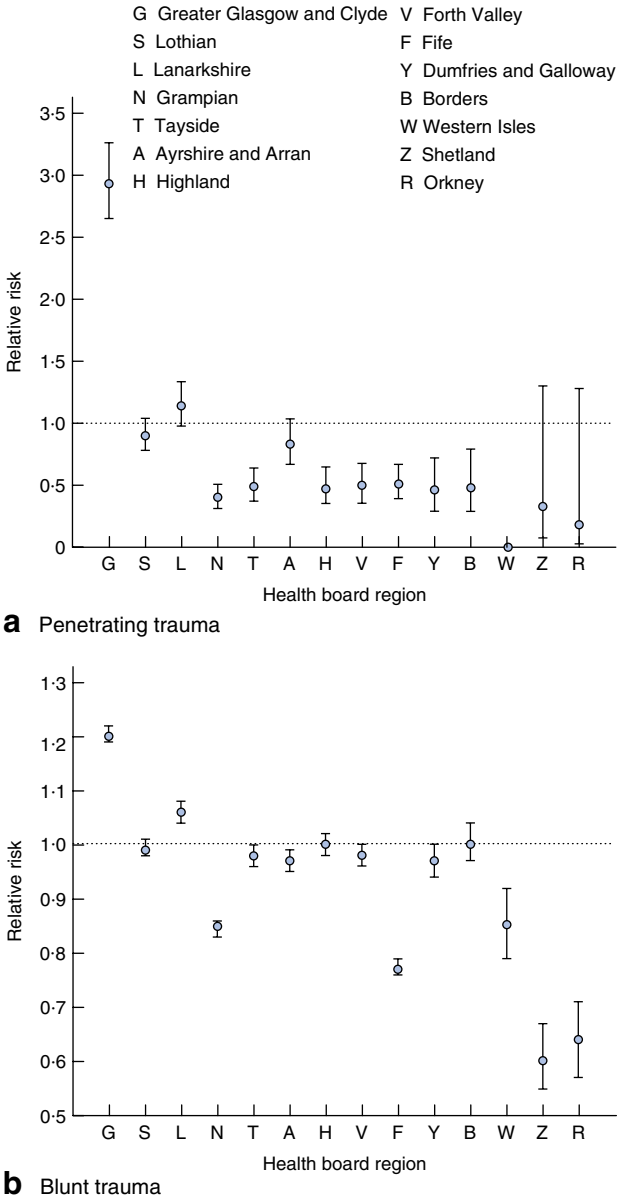


**Fig. 2** Relative risk of **a** penetrating and **b** blunt trauma incidents, by health board region. Error bars represent 95 per cent confidence intervals

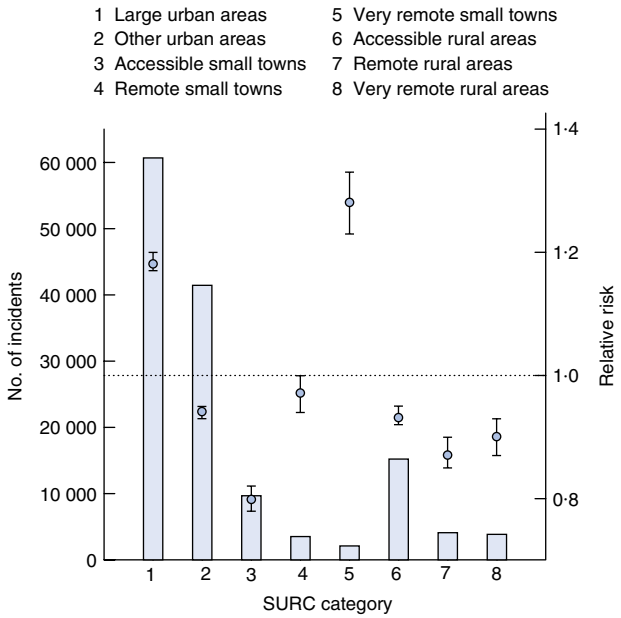


**Fig. 3** Number (bars) and relative risk (symbols), all incidents, by Scottish Urban Rural Classification (SURC) category. Error bars represent 95 per cent confidence intervals of relative risk

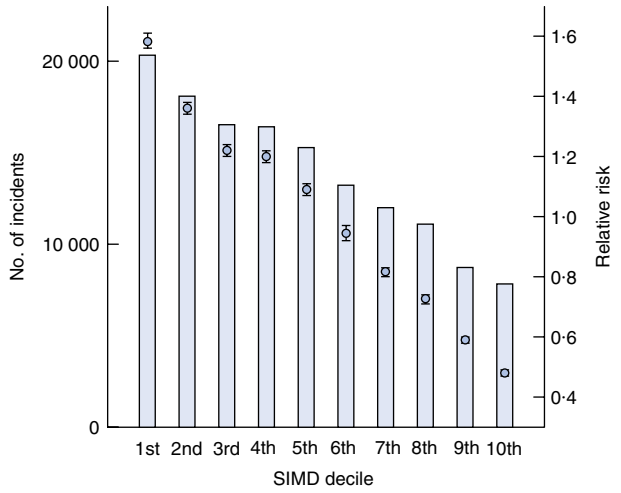


**Fig. 4** Number (bars) and relative risk (symbols) of incidents, any mechanism, by Scottish Index of Multiple Deprivation (SIMD) decile. Error bars represent 95 per cent confidence intervals of relative risk

large urban areas (relative risk 1·18, 1·17 to 1·20) than in categories 2, 3, 4, 6, 7 and 8, the relative risk was highest in very remote small towns (category 5; relative risk 1·28, 1·23 to 1·33). This pattern persisted for blunt trauma incidents. In contrast, the relative risk of being in a penetrating injury incident was much higher in large urban areas (2·36, 2·12 to 2·62) (*Table S1*, supporting information).

The number of incidents associated with physiological disturbance, which, in a region with a trauma system, would have resulted in triage to a level 1 or major trauma centre, was far higher in urban areas than in rural areas (*Table S2*, supporting information). The relative risk of being involved in an incident resulting in physiological disturbance was slightly higher in large urban areas (1·15, 1·10 to 1·21), and decreased slightly with increasing rurality

to 0·71 (0·60 to 0·84), with the exception of very remote small towns (relative risk 1·27, 1·04 to 1·56).

### Association with social deprivation

*Fig. 4* and *Table S3* (supporting information) show the relationship between the number of incidents, relative risk, incidence rate and social deprivation. The number of incidents involving blunt trauma was associated with the decile of SIMD rank. That is, the number of blunt trauma incidents in the most deprived regions was more than twice that of the least deprived areas (*Table S3* and *Fig. S2*, supporting information). However, for incidents involving penetrating trauma, the number of such incidents in the most deprived areas was much higher, 20 times that of the most affluent areas. The relative risk of an incident involving penetrating trauma in the most deprived decile was 5·42 (4·87 to 6·04) compared with the rest of Scotland (*Table S3* and *Fig. S3*, supporting information).

### Destination healthcare facility

Just over half of patients (53·1 per cent) were taken to a large general hospital and a further 38·6 per cent to a teaching hospital. Some 5·1 per cent were taken to a general hospital and 2·5 per cent to a community hospital (*Table S4*, supporting information). Patients with penetrating trauma were more likely to have been taken to a teaching hospital than patients with blunt trauma (49·6 *versus* 38·5 per cent respectively; $P < 0·001$). The proportions of patients with penetrating trauma who were taken to a large or small general hospital were 45·5 and 2·7 per cent respectively. There was little difference in level of the destination healthcare facility among patients with physiological derangement compared with those without. Overall, 53·3 per cent of patients with physiological derangements were taken to a large general hospital (*Table S5*, supporting information).

## Discussion

More than two-thirds of all the trauma incidents attended by the Scottish Ambulance Service occurred in more densely populated urban areas in Scotland. In contrast, only 5·8 per cent of incidents occurred in remote and very remote rural regions. The relative risk of an incident involving physiological instability was similar across Scotland, irrespective of rurality. The results suggest that the regionalization of trauma care in areas where the largest number of incidents occur would provide enhanced care for the majority of patients who incur injury.

The majority of patients injured in a rural setting do not require trauma centre care[9]. The present results furthermore demonstrate that the absolute number of incidents occurring in rural areas of Scotland is small. This does not mean that patients injured in remote regions should receive lesser care. On the contrary, an inclusive trauma system – with appropriate triage, clear referral pathways, and good primary retrieval and secondary transfer capability – would also enhance the care of those injured in remote and very remote areas. Mixed urban–rural populations are rarely distributed symmetrically, and other regions, including several US and Australian states, and parts of Scandinavia, have successfully overcome similar issues[7,18,23–26].

Blunt trauma, resulting primarily from falls or road traffic collisions, remains far more common than penetrating trauma in Scotland. In the present study the demographic and geospatial characteristics of incidents involving penetrating trauma differed from those caused by blunt trauma. This 'signal' is easily lost in the large volume of blunt trauma, but is important. Unlike blunt trauma, which had similar incidence rates and relative risks across Scotland, penetrating trauma was more common in urban areas, and in the Greater Glasgow and Clyde health board region in particular. It also affected a younger population, mostly men, and was strongly associated with social deprivation. Although not unexpected, this information is valuable, because it can be used to help guide primary prevention efforts.

The type of hospital to which patients with injuries were transported was, most likely, a reflection of the location where the injury occurred and the current Scottish policy to take injured patients to the nearest hospital. The fact that the distribution of destination healthcare facilities for patients with evidence of physiological derangement was almost identical to the distribution for those without it, suggests that there was no surreptitious triage. The higher probability of patients with penetrating trauma being taken to a teaching hospital was therefore most likely a function of the geographical location – more urban, and thus closer to teaching hospitals – where these incidents occurred.

The number of injured patients with physiological disturbances who were taken to non-teaching hospitals is concerning, and echoes the findings of a previous study on the destination healthcare facility of patients with suspected traumatic brain injury[27]. Although a hospital of specialties does not make a specialist hospital[28], many teaching hospitals at least have most of the required services on site. In contrast, even large general hospitals, to which more than half of injured patients with physiological derangements in this study were

taken, do not have critical services such as neurosurgery, cardiothoracic surgery or interventional radiology, and may lack other resources required to mount an effective trauma response.

This study has several limitations. First and most important is the use of dispatch codes, which are not diagnostic codes. This may have resulted in some inaccuracies in the selection of patients for inclusion in the study. However, the number of incidents retrieved from the ambulance service's record system (average 70 834 per year) was similar to the number with unintentional injuries admitted to hospital, as reported by the Information Services Division of the National Health Service in Scotland (61 977 for the year ending March 2010)[29], with the difference likely accounted for by discharges from emergency departments. This suggests that the use of dispatch codes for case selection resulted in a study population consistent with hospital admission data. The use of dispatch codes may have also resulted in inaccuracies in the categorization of patients by mechanism of injury. For example, some penetrating injuries (protocol 27) alternatively could have been coded as 'assaults' (protocol 04) or 'other traumatic injuries' (protocol 30), resulting in an underestimate of the prevalence of penetrating trauma. The mandatory recoding of all incidents by ambulance crews on completion of an episode (rather than acceptance or modification of the original dispatch code), which is regularly audited, provides some reassurance that the data are of sufficient quality. Second, the use of prehospital data from the electronic ambulance service record system may have led to inaccuracies. It is possible that some incidents were not recorded in the electronic database (they were recorded on paper or not recorded at all) and so were not included in the study. Although the authors have no measure of the completeness of electronic recording, it is estimated to be in excess of 80 per cent (Scottish Ambulance Service, 2012; personal communication). Because the ambulance service database was designed as an electronic patient record system rather than an audit or research tool, data are not always recorded consistently. For example, not all patients had basic demographic information noted such as age or even sex. However, the percentages of patients with missing data were relatively small. Third, the recording of vital signs might also have been inconsistent. The absence of a recorded blood pressure may have been due to the fact that a clinical assessment indicated there was no need to measure this parameter (because the injury was obviously minor) or because it could not be measured (because it was so low). The magnitude of the effect of these inconsistencies cannot be determined. Furthermore, owing to the limited data on mechanism and nature of injury, it was not possible to make full use of the Field Triage Decision Scheme and therefore to quantify fully the number of patients within this study population who would have been triaged to a trauma centre[19]. Fourth, patients taken to an emergency department by a means of transport other than the ambulance service are not represented in this analysis. The number of injured patients who presented in this way was probably small. However, particularly in rural areas, casualties could have been transported either by private vehicle or by military helicopter. Inability to count these patients probably contributes to a slight underestimate of the total volume of rural trauma. Fifth, data on secondary transfers of patients were not reported. This information would be helpful in establishing a more complete picture of pathways of trauma care in Scotland, but these data are not easily retrievable because they are not always distinctly coded as transfers. Finally, reliance on prehospital data creates other difficulties. The spectrum of injury severity among the patients in the present study ranged from the most minor to the very severe, but could not be quantified. Ideally, linkage of the data to a trauma registry would allow analysis by other key factors – such as injury severity – and, more importantly, outcome.

The use of prehospital data does, however, add to the evaluation and planning of trauma service delivery, providing information on volume, as well as a geographical overlay, informing on distribution. Scotland is unusual in that it is served by a single ambulance service, which enabled the authors to perform a comprehensive, population-based analysis. The value of such an analysis, even if data have to be collected from more than one provider, is clear, and the methodology employed may also be applicable to other countries and settings, and for the planning of other specialist services.

## Disclosure

The authors declare no conflict of interest.

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## Supporting information

Additional supporting information may be found in the online version of this article:

**Table S1** Number and rate of incidents, by Scottish Urban Rural Classification of location (Word document)

**Table S2** Number and rate of incidents involving physiological instability, by Scottish Urban Rural Classification of location (Word document)

**Table S3** Number and rate of incidents, by Scottish Index of Multiple Deprivation decile of incident location (Word document)

**Table S4** Destination healthcare facility, by mechanism of injury (Word document)

**Table S5** Destination healthcare facility, by physiology (Word document)

**Fig. S1** Number of incidents, any mechanism, by health board region (Word document)

**Fig. S2** Number and relative risk (with 95 per cent confidence interval) of incidents involving blunt trauma, by Scottish Index of Multiple Deprivation (SIMD) decile (Word document)

**Fig. S3** Number and relative risk (with 95 per cent confidence interval) of incidents involving penetrating trauma, by Scottish Index of Multiple Deprivation (SIMD) decile (Word document)